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ABSTRACT

This study focuses on the computer laboratory class as a learning environment in university courses. In it, two previously developed instruments, the Computer Laboratory Environment Inventory (CLEI) (based on an instrument designed by B. Fraser, G. Giddings, and C. McRobbie, 1993) and the Attitude towards Computing and Computing Courses Questionnaire (ACCC) (M. Newby and D. Fisher, 1997), were used. The CLEI has five scales for measuring students' perceptions of aspects of their laboratory environment. These are Student Cohesiveness, Open-Endedness, Integration, Technology Adequacy, and Laboratory Availability. The ACCC has four scales: Anxiety, Enjoyment, Usefulness of Computers, and Usefulness of the Course. These instruments were administered to 208 students taking computer courses (programming or applications). With the exception of Laboratory Availability, all the environment variables were found to correlate significantly with all attitudinal variables. The only environment variable with significant association with achievement was Student Cohesiveness. However, the results show that there are significant associations between the attitudinal variables, Anxiety, Enjoyment, and Usefulness of the Course and achievement. Regression analysis supports the findings that the environment variables make a significant contribution to the attitudinal variables, and these in turn make a significant contribution to achievement. Structural equation modeling supports the hypothesis that the computer laboratory environment affects achievement indirectly by directly affecting students' attitudes. (Contains 10 tables, 2 figures, and 27 references.) (Author/SLD)

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The Association Between Computer Laboratory Environment and Student Outcomes

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The Association between Computer Laboratory Environment and Student Outcomes

98 Abstracts

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Presented at the Australian Association for Research in Education Annual Conference, Adelaide, 1998

Abstract

This study focuses on the computer laboratory class as a learning environment in university courses. In it, two previously developed instruments, the Computer Laboratory Environment Inventory (CLEI) and the Attitude towards Computing and Computing Courses Questionnaire (ACCC) were used. The CLEI has five scales for measuring students' perceptions of aspects of their laboratory environment. These are Student Cohesiveness, Open-Endness, Integration, Technology Adequacy and Laboratory Availability. The ACCC has four scales, Anxiety, Enjoyment, Usefulness of Computers and Usefulness of the Course. These instruments were administered to a sample of 208 students taking computing courses within the Business School at Curtin University. The sample covered specialist programming courses as well as courses in which the students uses software tools such as spreadsheets. With the exception of Laboratory Availability, all the environment variables were found to correlate significantly with all attitudinal variables. The only environment variable with significant association with achievement was Student Cohesiveness. However, the results showed that there were significant associations between the attitudinal variables, Anxiety, Enjoyment and Usefulness of the Course and achievement. Regression analysis supported the findings that the environment variables made a significant contribution to the attitudinal variables, and these in turn made a significant contribution to achievement. Structural Equation Modelling supported the hypothesis that the computer laboratory environment affects achievement indirectly by directly affecting students' attitudes.

Background

Computer Laboratories

Computers have been used in higher education for over 30 years both as a subject of study in their own right and as a tool to assist in the learning process within other disciplines. They have also been used as a means of delivering educational material and for on-line assessment. More recently, there has been a rapid growth in the use of the Internet in most disciplines and a subsequent demand for suitable courses. In all courses where computers are used, computer laboratory classes play a major role. These classes can take a number of forms, the two most common being the closed or formal laboratory and the open laboratory (Prey, 1996; Lin, Wu & Chiou, 1996). The formal laboratory is scheduled in the same way as lectures and tutorials with specific exercises being set for students. They are generally staffed by a lecturer or higher grade academic. On the other hand, open laboratories allow students to come and go as they please with technical assistance being provided by laboratory demonstrators who are often senior students. Prey (1996) indicated that the open laboratory is the norm while Denk, Martin and Sarangarm (1993) noted that only about a third of the university courses surveyed in the United States used formal classes. From many perspectives such as hardware, software, staffing and space, computer laboratories are an expensive resource. The situation is further complicated by the obsolescence of both hardware and software most of which has a useful life of about three years. Despite the generally accepted importance of laboratory classes in computer based courses (Knox et al., 1996) little research has been carried out into their effectiveness at the university level.

Learning Environments

The conceptualisation and study of learning environments has been a subject of academic research for over thirty years (Fraser, 1991), and it arose from two independent programs which started at about the same time. As part of the evaluation of the Harvard Physics Project, Anderson and Walberg (1974) developed the Learning Environment Inventory (LEI). Working in a quite separate field, Moos developed a number of social climate scales, including those for use in correctional institutions (Moos, 1968) and psychiatric hospitals (Moos & Houts, 1968). These instruments led to the development of the Classroom Environment Scale (Trickett & Moos, 1973). Other instruments for assessing a number of different contextual learning environments have been developed since that time (Fraser, 1994).

The association between learning environment variables and student outcomes has provided a rationale and focus for the application of learning environment instruments. Research studies of classroom environments have demonstrated that perceived classroom environment may be predictive of student learning. For example, Haertel, Walberg and Haertel (1981) carried out a

meta-analysis which encompassed 823 classes in 8 subject areas and represented the perceptions of 17,805 students in 4 nations. They found that student achievement was enhanced in those classes which students felt had greater cohesiveness, satisfaction and goal direction and less disorganisation and friction. Fraser (1986) gives a table of 45 studies into associations between classroom environment and various student outcomes, cognitive, affective and behavioural. There have been many further investigations since that time and it is clear that a student's perception of classroom environment plays an important role in learning.

The increased use of computers in classrooms has led to studies to evaluate the effectiveness of computer assisted learning (Maor & Fraser, 1993; Teh & Fraser, 1994; Schuh, 1996; Fisher & Stolarchuk, 1997) and to investigate the association between gender, computer experience and perceived environment (Levine & Donitsa-Schmidt, 1995). This investigation extends the study of computers and learning environments into the tertiary level of education.

Methodology

This study involved the use of two previously developed instruments, one called the *Computer Laboratory Environment Inventory* (CLEI) for measuring aspects of a computer laboratory environment and the other, the *Attitude to Computers and Computing Courses Questionnaire* (ACCC) used to measure students' attitudes. The research focussed on whether a student's perception of aspects of their computer laboratory environment is associated with their achievement and their attitude towards computers and their course.

The Computer Laboratory Environment Inventory

The instrument for assessing computer laboratory environment is based on the actual version of the Personal form of the *Science Laboratory Environment Inventory* (SLEI) designed by Fraser, Giddings and McRobbie (1993). It has five scales, Student Cohesiveness, Open-Endedness, Integration, Technology Adequacy, and Laboratory Availability. The first three scales are derived directly from the SLEI, and the latter two are new scales designed for this instrument. The scales consist of seven items, with each item being measured on a Likert scale of 1 to 5 with some questions being reversed. Table 1 gives a description of each scale with a sample item.

Table 1
Description of CLEI scales

Scale	Description	Sample Item
Student Cohesiveness	Extent to which students know, help and are supportive of each other	I get on well with students in this laboratory class (+)
Open-endedness	Extent to which the laboratory activities encourages an open-ended divergent approach to use of computers	There is opportunity for me to pursue my own computing interests in this laboratory class (+)
Integration	Extent to which the laboratory activities are integrated with non-laboratory and theory classes	The laboratory work is unrelated to the topics that I am studying in my lecture (-)
Technology Adequacy	Extent to which the hardware and software is adequate for the tasks required	The computers are suitable for running the software I am required to use (+)
Laboratory Availability	Extent to which the laboratory is available for use	I find that the laboratory is crowded when I am using the computer (-)

Items designated (+) are scored 1,2,3,4 and 5, respectively for responses Almost Never, Seldom, Sometimes, Often, Almost Always
Items designated (-) are scored 5,4,3,2 and 1, respectively for responses Almost Never, Seldom, Sometimes, Often, Almost Always

In previous studies (Newby & Fisher, 1997a, 1997b), the Cronbach alpha reliability coefficients of the scales were shown to vary between 0.60 and 0.89 and mean correlation with other scales from 0.08 to 0.22. This indicated that the scales are satisfactory in terms of internal consistency, and there is little overlap in what they measure.

Attitude towards Computers and Computer Courses Questionnaire

The instrument for assessing students' attitudes towards computers and computer courses (ACCC) has been described in earlier

studies (Newby & Fisher, 1997a, 1997b). For assessing attitude towards computers, the scales Anxiety, Enjoyment, and Perceived Usefulness of Computers were based upon an instrument devised by Loyd and Loyd (1985). They also included a Confidence scale but differentiating between lack of confidence and anxiety proved difficult so the Confidence scale was omitted. A fourth scale was included to measure the student's perception of the usefulness of the course. As with the CLEI, all the scales have seven items and a description of the scales used in the instrument is given in Table 2 together with a sample item from each scale.

Table 2
Description of ACCC Scales

Scale	Description	Sample Item
Anxiety	Extent to which the student feels comfortable using a computer	Working with a computer makes me very nervous (+)
Enjoyment	Extent to which the student enjoys using a computer	I enjoy learning on a computer (+)
Usefulness of Computers	Extent to which the students believes computers are useful	My future career will require a knowledge of computers (+)
Usefulness of Course	Extent to which the student found the course useful	I do not think I will use what I learned in this class (-)

Items designated (+) are scored 1,2,3,4 and 5, respectively for responses Strongly Disagree, Disagree, Not Sure, Agree, Strongly Agree
Items designated (-) are scored 5,4,3,2 and 1, respectively for responses Strongly Disagree, Disagree, Not Sure, Agree, Strongly Agree

Sample

The instrument was administered to 208 students undertaking courses involving a laboratory component within the Business School of Curtin University in Western Australia. The sample was representative with respect to gender, age, mode of study, and level of study (undergraduate / postgraduate). The classes surveyed included those in which the development of software was the focus of study, such as Information Systems, and others in which the computer was used as a tool for word processing, spreadsheets and access to the Internet. The computer systems used were standalone PCs, networked computers, or a multi-access system.

Achievement

Achievement was measured as the grade obtained in the course, as a mark out of 100. Depending on the way the course had been organised, this grade consisted of one or more of the following components, examination, assignments and laboratory exercises. Not all courses involved all three components, although most had a final examination and at least one assignment which required the use of a computer. Using means and standard deviations obtained for each course, the grade was converted into a z-score. Of the 208 students, 142 provided their student number allowing their grades to be determined.

Results

Associations between Computer Laboratory Environment and Attitudinal Outcomes

Table 3 presents results of the analysis of associations between students' perceptions of their computer laboratory environment and their attitudes towards computers and the course in terms of simple correlation coefficients (r) and standardised regression coefficients (β). It also shows the square of the adjusted multiple correlation coefficient (R^2).

Examination of the simple correlation coefficients show that 17 out of a possible 20 relationships are significant ($p < .05$). With the exception of Laboratory Availability, all environment variables correlate significantly with the attitudinal variables, negatively in the case of Anxiety. In addition, Laboratory Availability correlates with Usefulness of the Course.

The regression analysis shows 13 significant relationships out of 20, with all four multiple correlations being significant.

Table 3
Associations between the CLEI scales and the ACCC scales

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	Strength of Environment-Outcome Association							
Scale	Anxiety		Enjoyment		Usefulness of Computers		Usefulness of Course	
	r	β	*r*	β	*r*	β	*r*	β
Student Cohesiveness	-0.18**	-0.16*	0.22**	0.17*	0.17*	0.15*	0.26***	0.17**
Open-Endedness	-0.25***	-0.22***	0.25***	0.25***	0.14*	0.18*	0.38***	0.38***
Integration	-0.17**	-0.14*	0.22**	0.16*	0.20**	0.10	0.38***	0.37***
Technology Adequacy	-0.26***	-0.25***	0.26***	0.12	0.26***	0.06	0.26***	0.13*
Laboratory Availability	-0.04	0.12	0.03	-0.12	0.04	-0.10	0.14*	-0.02
Multiple R^2	0.15***		0.12***		0.05*		0.35***	

*$p < .05$, **$p < .01$, ***$p < .001$ N=208

Four of out the five independent variables contributed significantly to the prediction of Anxiety with Open-Endedness and Technology Adequacy contributing most. Altogether, 15% of the variability in Anxiety was predicted by knowing the values of the environment variables. Three of the five independent variables contributed significantly to the prediction of Enjoyment with Open-Endedness and Student Cohesiveness contributing most. Altogether, 12% of the variability in Enjoyment was predicted by knowing the values of the environment variables. Student Cohesiveness and Open-Endedness contributed significantly to the prediction of Usefulness of Computers. Only 5% of the variability in Usefulness of Computers was predicted by knowing the values of the environment variables. Four of out the five independent variables contributed significantly to the prediction of Usefulness of Class with Open-Endedness, Integration and Student Cohesiveness contributing most. Altogether, 35% of the variability in Usefulness of Class was predicted by knowing the values of the environment variables.

Associations between Environment and Achievement

Associations between the computer laboratory environment and overall grades are shown in Table 4. It can be seen that only Student Cohesiveness correlates significantly ($p < .05$) with grade, and the standardised regression coefficient is also significant. However, the multiple correlation coefficient is not significant.

Table 4
Associations between environment variables and overall grade

	r	β
Student Cohesiveness	0.18*	0.19*
Open-Endedness	0.07	0.07
Integration	0.05	0.02
Technology Adequacy	0.13	0.17
Laboratory Availability	0.08	0.01
Multiple R^2	0.04	

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*$p < .05$

Associations between Attitude and Achievement

Associations between the attitudinal variables and overall grade shown in Table 5 indicate that three out of four simple correlations are significant ($p < .05$), as are three out of the four regression coefficients. The multiple correlation coefficient R is also significant ($p < .001$). The simple correlations indicate that Anxiety, Enjoyment and Usefulness of Course are associated with achievement. However, the regression coefficients demonstrate that Enjoyment, Usefulness of Course and Usefulness of Computers contribute significantly to the prediction of achievement.

Table 5
Associations between attitudinal variables and overall grade

	r	β
Anxiety	-0.20*	-0.04
Enjoyment	0.25**	0.26*
Usefulness of Computers	0.01	-0.22*
Usefulness of Course	0.29**	0.24*
Multiple R^2	0.11***	

*$p < .05$, **$p < .01$, ***$p < .001$

It can be seen that the standardised regression coefficient (β) for Usefulness of Computers is significantly different from zero, and is substantially larger than the absolute value of the simple correlation between Usefulness of Computers and achievement measured by overall grade. This indicates that Usefulness of Computers could be a suppressor variable (Tabachnick & Fidell, 1996). A suppressor variable is one which contributes to increasing the multiple R^2 by virtue of its correlation with other independent variables. Further analysis was carried out by carrying out standard multiple regressions on achievement with the independent variables, individually and in all combinations. From this analysis it was found as a single variable, Usefulness of Computers makes no contribution to predicting achievement. When it is included with any other variables or set of variables, it increases the multiple R^2, in most cases significantly. This demonstrates that Usefulness of Computers is a suppressor variable, and it increases the variance accounted for by both Enjoyment and Usefulness of the Course by suppressing variance due to their perception on how useful computers are or will be. To summarise, three out of the four attitudinal variables contribute significantly to the prediction of achievement, with Usefulness of Computers being a suppressor variable. In all, 11% of variability in achievement is accounted for by the attitudinal variables.

Structural Equation Modelling

Proposed model

In order extend the investigation of the association between the computer laboratory environment variables, as measured by the scales of the CLEI and student outcomes, as measured by the scales of the ACCC and student grade, a model is proposed and this is shown in Figure 1. There are two latent variables, Environment and Attitude. The latent variable Environment affects the responses to the questions relating to the scales of the CLEI and the variable Attitude the responses to the questions relating to the scales of the ACCC. Further it is hypothesised that there is a causal relationship between Environment and Attitude and between Attitude and achievement, as measured by z-score. The environment variables, the attitudinal variables and achievement are observed endogenous variables, and each one has an error variable associated with it. Attitude is a latent endogenous variable so has a disturbance variable associated with it. Environment is a latent exogenous variable.

Analysis of the Model

The data were run with Amos 3.6 (AMOS, 1996), and the model converged in 10 iterations. A summary of the results is shown in Tables 6 and 7.

Table 6
Regression Coefficients for the Model of Environment-Attitude-Achievement

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Relationship	B	β
Attitude ← Environment	2.49	0.96**
Student Cohesiveness ← Environment	0.88	0.32**
Open-Endedness ← Environment	1.00	0.41#
Integration ← Environment	0.93	0.25**
Technology Adequacy ← Environment	0.83	0.25**
Laboratory Availability ← Environment	0.67	0.17
Anxiety ← Attitude	-0.77	-0.57**
Enjoyment ← Attitude	0.72	0.64**
Usefulness of Computers ← Attitude	0.28	0.32**
Usefulness of Course ← Attitude	1.00	0.94#
Achievement ← Attitude	0.07	0.34**

used for identification, ** $p < .01$

Table 7
Covariances and Correlation Coefficients for Original Model of Environment-Attitude-Achievement

Relationship	Covariance	Correlation
Anxiety ↔ Enjoyment	-3.84	-0.31
Anxiety ↔ Usefulness of Computers	-2.08	-0.18
Anxiety ↔ Usefulness of Course	2.44	0.48
Enjoyment ↔ Usefulness of Computers	4.59	0.50**
Enjoyment ↔ Usefulness of Course	-2.58	-0.66
Usefulness of Computers ↔ Usefulness of Course	0.34	0.09

used for identification, ** $p < .01$

From these it can be seen that the regression coefficient of Availability on Environment is not significant. Also, the only covariance that is significant is the one between Enjoyment and Usefulness of Computers.

There are many indices for measuring how well a model fits the data (Schumaker & Lomax, 1996, Chap. 7), and the ones given in Table 8 are the χ^2 degrees of freedom ratio (χ^2/df), the Goodness of Fit Index (GFI), the Adjusted Goodness of Fit Index (AGFI), the Root Mean Square Residual (RMR), the Root Mean Square of the Error of the Approximation (RMSEA), and the Expected Value of the Cross Validation Index (EVCI). The ratio χ^2/df is a frequently used measure, and a value of less than 2 is considered to show a very good fit. The GFI measures the relative amount of variance and covariance in the data accounted for by the proposed model. Values in excess of 0.90 are considered to indicate a good fit. The AGFI makes allowance for the complexity of the model and again a figure above 0.90 is considered a good fit. The RMR measures the amount of remaining variance not explained by the model and in figure of 0.05 indicates a good fit. The RMSEA is a measure of the discrepancy of

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the fitted model per degree of freedom, and a value of 0.05 shows a close fit with a value of 0.08 representing reasonable errors (Jöreskog, 1993). The ECVI is a measure of the discrepancy between the fitted covariance matrix in the analysed sample and the expected covariance matrix obtained that would be obtained in another sample of the same size (Browne & Cudeck, 1993). The smaller the value of the ECVI, the better the fit.

As can be seen from Table 8, for this model, the Goodness of Fit Index (GFI) is 0.933, χ^2 is 57.29, χ^2/(degrees of freedom) is 1.975, the RMR 0.116, the RMSEA is 0.083 and the ECVI is 0.775, with a 90% confidence interval of (0.649, 0.956). The value of the RMR is well outside the acceptable limits but the other indices would indicate that the model is a reasonable fit.

The model was refined by removing the least significant covariances at each stage, and Figure 2 shows the model that was obtained. In this model, the only covariances are between the errors of Anxiety and Enjoyment and between Enjoyment and Usefulness of Computers. Table 8 gives the values of the fit indices for the two previous models.

Table 8
Comparisons of Models for Environment-Attitude-Achievement

Model	χ^2	df	χ^2/df	GFI	AGFI	RMR	RMSEA	ECVI
1	57.29	29	1.975	0.933	0.873	0.116	0.083	0.775
2	64.27	33	1.948	0.924	0.873	0.115	0.082	0.768

Discussion

Of the two models, model 3 has the smaller values for ECVI and χ^2/ df, but model 1 has a higher value of the GFI. The standardised regression weights for model 2 are given in Table 9, and the covariances and correlation coefficients in Table 10.

This model indicates there are correlations between anxiety and enjoyment, and between enjoyment and perceived usefulness of computers. The regression coefficients are significant ($p<.01$) for all relationships, except between Environment and Laboratory Availability which is significant at the 0.05 level. The model shows that the standardised regression coefficient for the effect of environment on attitude is 0.95, and for attitude on achievement is 0.35, so the indirect effect of environment on achievement has a regression weight of 0.33.

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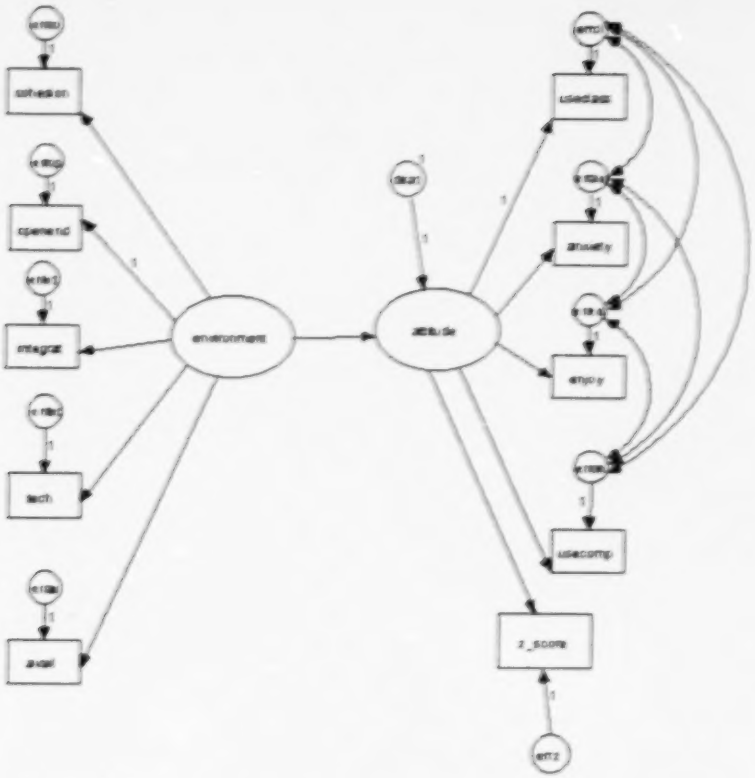

Figure 1. Original proposed model for Environment-Attitude-Achievement

Figure 2. Final proposed model of Environment-Attitude-Achievement

Table 9
Regression Coefficients for the Revised Model for Environment-Attitude-Achievement

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Relationship	B	β
Attitude ← Environment	2.08	0.95**
Student Cohesiveness ← Environment	0.94	0.35**
Open-Endedness ← Environment	1.00	0.42#
Integration ← Environment	0.98	0.28**
Technology Adequacy ← Environment	1.04	0.32**
Laboratory Availability ← Environment	0.92	0.24*
Anxiety ← Attitude	-0.79	-0.51**
Enjoyment ← Attitude	0.70	0.56**
Usefulness of Computers ← Attitude	0.40	0.40**
Usefulness of Course ← Attitude	1.00	0.83#
Achievement ← Attitude	0.08	0.35**

used for identification, *$p < .05$, **$p < .01$

Table 10
Covariances and Correlation Coefficients for the Revised Model for Environment-Attitude-Achievement

Relationship	Covariance	Correlation
Anxiety ↔ Enjoyment	-4.59	-0.34**
Enjoyment ↔ Usefulness of Computers	3.93	0.42**

**$p < .01$

Discussion

The only non-significant associations between the environment variables and the attitudinal variables involve Laboratory Availability, indicating that this is not a factor in influencing attitude except in perceived usefulness of the course. There are strong correlations between all the environment variables and both Anxiety (negatively) and Usefulness of Course. Enjoyment is correlated strongly with all environment variables except Laboratory Availability with which it is still correlated significantly. Usefulness of Computers is correlated with Integration, Technology Adequacy and Student Cohesiveness.

The most important observations from these results are the associations between both anxiety and perceived usefulness of the course and all environment variables. This could imply that a laboratory class which is integrated with non-laboratory classes, where the approach is open-ended, where the students are a more cohesive group, where the technology provided is suitable for the task at hand, and where laboratories are freely available, will lead to a reduction in anxiety about computers and a perception that the course is more useful. From another viewpoint, it can be seen that there are associations between both course integration and technology adequacy and all attitudinal variables. This highlights both the importance of course design, particularly the relationship between laboratory classes and non-laboratory classes, and the need to provide hardware and software that is adequate for the exercises assigned to students. This latter point also means that the lecturer running the course must take hardware and software availability into account when designing laboratory work.

The regression analysis in general supported the findings of the simple correlation analysis, although there were some differences. Laboratory Availability was not a significant predictor for any of the attitudinal variables. Technology Adequacy correlates significantly with all the attitudinal variables, but the regression analysis indicates that it contributes significantly to

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only two of them, Anxiety and Usefulness of the Course.

Usefulness of the Course is the attitudinal variable whose variability is most explained by the environment variables. The most significant contributions comes from Open-Endedness (with a unique contribution of 14%) and Integration (with 12%) with minor contributions from Student Cohesiveness and Technology Adequacy. This would imply that courses whose laboratory classes are more open-ended and more integrated with the non-laboratory classes are perceived to be more useful.

The environment variables explained 15% of the variability of Anxiety with Technology Adequacy and Open-Endedness accounting for 5% each. There were minor but significant contributions from Student Cohesiveness and Integration. These results suggest that the suitability of the hardware and the software for the tasks that the students are required to carry out is important in reducing their anxiety about using computers. They also appear to imply that reduced anxiety is associated with a more open-ended approach to laboratory classes.

For Enjoyment, 12% of its variability is explained by the environment variables, with the main contribution coming from Open-Endedness (6%) and minor contributions from Student Cohesiveness and Integration.

The environment variable whose variability is least explained by the environment variables is Usefulness of Computers. Only 5% is explained with significant contributions from only Open-Endedness (3%) and Student Cohesiveness (2%). It would seem that students' perceptions of the usefulness of computers are dependent on other influences and their computer laboratory environment does little to change this perception.

Examining the contribution that the environment variables make to the attitudinal variables, it can be seen that Open-Endedness makes a significant contribution to all of them, implying that a laboratory class which encourages a divergent approach reduces anxiety, increases enjoyment, perception of the course's usefulness and perception of the usefulness of computers. Except for Anxiety, Technology Adequacy has a minimal effect on the attitudinal variables. This runs counter to much anecdotal evidence, but for this sample could be explained by the fact that the hardware and software are suitable and so the students do not consider it to be an issue. A similar observation could be made about Laboratory Availability.

The results for the environment variables show that only Student Cohesiveness is associated significantly with achievement ($p < .05$). The lack of association of the other variables is possibly explained by the way in which achievement is measured. It is the composite grade obtained summing a number of components, and in most cases, it is dominated by a formal examination, which contributes at least 50%. Influence of computer laboratory environment on formal examinations will be indirect so may not be measurable. The component that is influenced most by laboratory environments is laboratory exercises, but these usually contribute least, if at all, to the final grade. The other major component is a set of assignments, which are practical in nature. In many cases, students work together on assignments, even where they are intended to be individual pieces of work. This could explain the association between student cohesiveness and achievement.

The standard multiple regression of environment variables on achievement produced a multiple regression R which was not significant, and so achievement cannot be predicted from these variables.

For the attitudinal variables, Anxiety, Enjoyment and Usefulness of Course are correlated significantly with achievement. This would imply that achievement in terms of grade is higher for those students with lower anxiety about computers, enjoy using them more, and who perceive the course to be more useful. Perceived usefulness of computers was found not to associated with achievement. The association between lack of anxiety and achievement supports previous findings (Marcoulides, 1988). The regression analysis resulted in a multiple R that was significant ($p < .001$), with the variables Enjoyment, Usefulness of Course and Usefulness of Computers being significant predictors of achievement.

Structural equation modelling supported a proposed model in which the effect of environment on achievement is indirect. In this model, environment affects attitude, which in turn affects achievement with the indirect effect of environment on achievement having a regression weight of 0.33.

Significance of Study

The significance of this study is that it is one of the first that has investigated the effectiveness of computer laboratory classes in a university setting in which the computer is central to the discipline being studied. The results demonstrate that the computer laboratory environment variables have significant associations with students' attitudes towards computers and the course. This would suggest that computer laboratory classes should be integrated with theory and other non-laboratory classes, that laboratory work should be open-ended in nature, and that the hardware and software should be taken into account when designing laboratory exercises and assignments. The fact that 35% of the variance in perceived usefulness of the course is explained by the environment variables highlights the importance of laboratory classes in courses in which computer systems are integral part of the curriculum. Designing closed computer laboratory classes as part of a course involves a considerable

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commitment on part of both faculty and departments, but it seems that this investment would be worth the effort.

It appears that there is little direct association between computer laboratory environment and achievement, but structural equation modelling supported a model in which environment variables made a significant contribution to the attitudinal variables, and these in turn made a significant contribution to achievement.

References

AMOS. (1996). *AMOS Users' Guide Version 3.6*. Chicago: Smallwaters Corporation.

Anderson, G. J., & Walberg, H. J. (1974). Learning environments. In H. J. Walberg (Ed.), *Evaluating educational performance: A sourcebook of methods, instruments, and examples*. Berkeley, CA : McCutchan.

Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equating models* (pp. 136-159). Newbury Park, CA: Sage.

Denk, J., Martin, J., & Sarangarm, S. (1993). Not yet comfortable in the classroom: A study of academic computing at three Land-Grant Universities. *Journal of Educational Technology Systems*, *22*(1), 39-55.

Fisher, D. L., & Stolarchuk, E. (1997, November). *The effects of using laptop computers on achievement, attitude to science and classroom environments in science*. Paper presented at the Annual Conference of the Western Australian Science Education Association, Perth.

Fraser, B. J. (1991). Two decades of classroom environments research. In B. J. Fraser & H. J. Walberg (Eds.), *Educational environments: Antecedents, consequences and evaluation*. London : Pergamon Press.

Fraser, B. J. (1994). Research on classroom and school climate. In D. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 493-541). New York: Macmillan.

Fraser, B. J., Giddings, G. J., & McRobbie, C. J. (1993). Development and cross-national validation of a laboratory classroom environment instrument for senior high school science. *Science Education*, *77*, 1-24.

Fraser, B. J. (1986). *Classroom environment*. London: Croom Helm.

Haertel, G. D., Walberg, H. J., & Haertel, E. H. (1981). Socio-psychological environments and learning: A quantitative synthesis. *British Educational Journal*, *7*, 27-36.

Jöreskog, K. G. (1993). Testing structural equation models. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equating models* (pp. 294-316). Newbury Park, CA: Sage.

Knox, D., Wolz, U., Joyce, D., Koffman, E., Krone, J., Laribi, A., Myers, J. P., Proulx, V. K., & Reek, K. A. (1996). Use of laboratories in Computer Science education: Guidelines for Good Practice. *SIGCSE Bulletin, Special Edition - Integrating Technology into Computer Science Education*, 167-181.

Levine, T., & Donitsa-Schmidt, S. (1995). Computer experience, gender, and classroom environment in computer-supported writing classes. *Journal of Educational Computing Research, 13*(4), 337-357.

Lin, J. M-C., Wu, C-C., & Chiou, G-F. (1996). Critical concepts in the development of courseware for CS closed laboratories. *SIGCSE Bulletin, Special Edition - Integrating Technology into Computer Science Education*, 14-19.

Loyd, B. H., & Loyd, D. E. (1985). The reliability and validity of an instrument for the assessment of computer attitudes. *Educational and Psychological Measurement*, *45*, 903-908.

Maor, D., & Fraser, B. J. (1993). Use of classroom environment perceptions in evaluating inquiry-based computer learning. In D. L. Fisher (Ed.), *A Study of Learning Environments: Volume 7*. Perth, Western Australia : Curtin University of Technology.

Marcoulides, G. A. (1988). The relationship between computer anxiety and computer achievement. *Journal of Educational Computing Research*, *4*(2), 151-158.

Moos, R. H. (1968). The assessment of the social climates of correctional institutions. *Journal of Research in Crime and Deliquency*, *5*, 174-188.

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Moos, R. H., & Houts, P. (1968). Assessment of the social-atmosphere of psychiatric wards. *Journal of Abnormal Psychology, 73*, 595-604.

Newby, M., & Fisher, D. L. (1997a). An instrument for assessing the learning environment of a computer laboratory. *Journal of Educational Computing Research, 16*(2), 179-190.

Newby, M., & Fisher, D. L. (1997b). Development and use of the Computer Laboratory Environment Inventory. *Proceedings, 14th Annual Conference of the Australian Society for Computers in Tertiary Education*. 430-435.

Prey, J. C. (1996). Cooperative learning and closed laboratories in an undergraduate Computer Science curriculum. *SIGCSE Bulletin, Special Edition - Integrating Technology into Computer Science Education*, 23-24.

Schuh, K. L. (1996). The lecture classroom environment and its effect on change in computer anxiety of students taking computer proficiency classes. *Journal of Educational Computing Research, 15*(3), 241-259.

Schumacker, R. E., & Lomax, R. G. (1996). *A beginner's guide to structural equation modeling*. Mahwah, NJ: Lawrence Erlbaum Associates.

Tabachnick, B. G. & Fidell, L. S. (1996). *Using multivariate statistics* (3rd ed.). New York: HarperCollins.

Teh, G. P. L., & Fraser, B. J. (1994). Development and validation of an instrument for assessing the psycholosocial environment of computer-assisted learning classrooms. *Journal of Educational Computing Research, 12*(2), 177-193.

Trickett, E. J., & Moos, R. H. (1973). Social environment of junior high and high school classrooms, *Journal of Educational Psychology, 65*, 93-102.

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